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POWER

CORRES CONTROL  
OUTGOING LTR NO  
87 RF-1824

Rocky Flats Plant  
North American Space Operations  
Rockwell International Corporation  
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000024528

Contractor to U S Department of Energy

March 11, 1987

87-RF-1824

Albert E Whiteman  
Area Manager  
DOE, RFAO

## ROCKY FLATS PLANT FLUIDIZED BED INCINERATOR

The information contained in the letter is for the attention of  
Ronald D. Reed

Please find attached the Rocky Flats Plant Fluidized Bed Incinerator  
Radioactive Emissions and Health Risks assessment. If you have any  
questions, please contact Nancy M. Daugherty of my staff on Extension 7005.

*George W. Campbell*  
George W. Campbell, Director  
Health, Safety and Environment

Enc. (1)

Orig. and 1 cc - A E. Whiteman

DIST	R	F
SANCHINI D J	X	X
BADER C P		
CAMPBELL G W	X	X
HOOD R C		
KINZER J E		
KIRBY W A		
LANGHEIM G R	X	X
McNETT J F		
PETERSON R G		
SHANNON W M		
SMITH R E		
VEJVODA E		
WEIDNER C W		
WESTON W F	X	X
WILSON G L		
WOZNAK B D		
YODER R E		
YOUNG E R		
<i>meyer D W</i>	X	X

BETCHER D H		
CHANDA R N		
FREIBERG K J		
HARMAN L K		
HEBERT J L		
HOEY J B		
HOFFMAN R B		
KREIG D M		
LIM B W		
LOUDENBURG G E		
NAIMON E R		
NEWBY R L		
TURNER H L		
VELASQUEZ R N		

CORRES CONTROL	X	X
<i>Daugherty, N.</i>	X	X
<i>Parker G</i>	X	X
<i>Settle</i>	X	X
<i>Wicklund</i>	X	X

CLASSIFICATION	
UNCLASSIFIED	X
CONFIDENTIAL	X
SECRET	

AUTH CLASSIFIER SIG  
*[Signature]*  
DATE *3/15/87*  
IN REPLY TO LTR NO  
*N/A*

DEC #  
LTR APPROVALS

ORIG & TYPIST INITIALS  
*NMD/GWC/KUH*

## ROCKY FLATS PLANT FLUIDIZED BED INCINERATOR

### RADIOACTIVE EMISSIONS AND HEALTH RISKS

#### INTRODUCTION

Total emissions, air concentrations, and projected radiation doses were calculated for both the verification run and for expected routine operations for the Rocky Flats Plant Fluidized Bed Incinerator (FBI). While these calculations do not represent as comprehensive a pathway analysis as has been done previously for all Plant emissions in the Rocky Flats Environmental Impact Statement (EIS), they do include the major contributions to radiation dose and provide estimates of the general significance of the FBI operation on public health.(US80) Several assumptions were incorporated into the calculations which would tend to overestimate the resulting emissions, concentration, and dose values. Results of the calculations indicate that concentrations and projected radiation doses would be far below applicable radiation protection standards. Radiation doses would be insignificant in comparison to those received by Denver area residents from exposure to naturally occurring radiation and radioactive materials.

#### BASIS OF THE CALCULATIONS AND ASSUMPTIONS MADE

##### Verification Run -

Six individual runs currently are proposed for the FBI verification run. Three of the runs will be for liquid waste and three for solid waste. Each run will last for 4 hours. One of the liquid waste runs will include depleted-uranium-contaminated waste. One of the solid waste runs would include depleted-uranium-contaminated waste and the remaining two would include waste contaminated with plutonium. Specific information on the six runs is given in the accompanying tables.

The depleted uranium concentration in the verification run will be 0.17 weight percent. The plutonium concentration will be 100 nanocuries (nCi) per gram of waste. The alpha-radiation specific activity of depleted uranium is  $3.8 \times 10^{-7}$  Curies per gram and of plutonium is 0.0732 Curies per gram. Beta radiation was not included in these specific activities because beta radiation is a relatively insignificant contributor to dose and omitting it in the specific activity values tends to overestimate the calculated concentrations and doses. Additional information on isotopic composition and specific activity may be found in the Rocky Flats Plant Environmental Impact Statement (EIS).(US80)

The air emission flow rate used for the building exit is 8636

cubic meters per hour. This is based on the average flow rate for the ventilation system serving the FBI in 1986. It is used to calculate the radioactivity concentration of air at the point it exits the building.

The relative concentration of radioactivity at the Plant boundary ( $X/Q$ ) (from a unit concentration release) downwind from the emission point is calculated using the Gaussian form of solution to diffusion equations. The symbol,  $X$ , represents the concentration (in picocuries per cubic meters) and the symbol,  $Q$ , represents the radioactivity emission rate (in picocuries per second). The Gaussian distribution yields a peak value along the centerline of the emitted plume with the values falling off exponentially in both directions normal to the wind direction.

For the calculations in this report, the following assumptions were made, many of which tend to maximize the calculated concentrations:

- 1) Releases are at ground-level from a point source;
- 2) There is no depletion of the airborne effluent by washout, settling, or surface deposition;
- 3) There are no significant terrain changes near the Plant site;
- 4) Plume centerline concentrations are calculated;
- 5) No reduction in concentration is made for building wake dilution;
- 6) Wind speed is 3 meters per second, atmospheric stability corresponds to a Pasquill category E;
- 7) The hypothetical individual receiving the dose was located at the nearest Plant boundary (1.2 miles) and was impacted by the centerline effluent plume concentration throughout all incinerations performed. In fact no one resides at this location.

The resulting equation for relative concentration, is

$$X/Q = 1/(\pi \sigma_y \sigma_z \bar{u}) = 3.5 \times 10^{-5} \text{ s/m}^3$$

as defined in the Rocky Flats Environmental Impact Statement. (US80)

The breathing rate assumed for the postulated impacted individual was  $2.66 \times 10^2$  milliliters per second.

A minimum a five stages of High Efficiency Particulate Air (HEPA) filters will be used to filter particulates from the FBI air effluent prior to its exiting the building. Each of the HEPA filters is individually tested and certified to provide a minimum

filtration efficiency of 99.97%. Once installed the HEPA bank is tested to assure a filtration efficiency of 99.95% or more. For these calculations, it was assumed that the first bank of HEPA filters provides a filtering efficiency of 99.95% and that the subsequent four banks provide an efficiency of 99.8% each. The resulting HEPA filter reduction factor is  $8 \times 10^{15}$ . This is consistent with the assumptions made in the EIS.

It also was assumed in the calculations that no plutonium and uranium remain trapped in the incinerator fluidized bed ash and that all of the radioactivity is contained in the exiting incinerator air stream. This assumption maximizes the radioactivity which challenges the HEPA filters.

Radiation dose conversion factors for uranium and plutonium are 50-year committed effective dose equivalent conversion factors calculated from radiation dosimetry data provided in Publication No. 30 of the International Commission on Radiological Protection. (IN79) Uranium-238 was used to represent depleted uranium and plutonium-239 was used for plutonium. These isotopes are the major constituents of the isotopic mixtures of these materials and the most significant contributors to radiation dose from them. The 50-year committed effective dose equivalent conversion factor for uranium is  $1.2 \times 10^2$  rem per microcurie inhaled and for plutonium is  $5.1 \times 10^2$  rem per microcurie inhaled. Inhalation is the predominant pathway for radiation dose for both of these materials; all other pathways are insignificant in comparison.

#### Routine Operations -

For emission, concentration and dose calculations for routine operations of the FBI, the plutonium concentration in the waste was assumed to be 100 nanocuries per gram of waste. During routine operations, actual plutonium concentrations should be much less than this maximum. For these calculations the uranium concentration was assumed as  $1 \times 10^4$  picocuries per liter of waste. This is at the high end of the concentrations currently measured in candidate liquid waste streams for the FBI. This concentration was assumed for both liquid and solid waste. It is expected that the solid waste concentration would be lower.

It was assumed that 200 tons of low level waste would be incinerated per year, although current expectations are somewhat lower than this. The maximum feed rate of waste would be 150 pounds per hour for solids and 60 pounds per hour for liquids. For these calculations, a feed rate of 150 pounds per hour was used for all of the waste, because this rate tended to overestimate resulting concentrations and doses.

Specific activities, air emission flow rate, X/Q, HEPA filtration efficiency, breathing rate, and radiation dose conversion factors all were the same as those assumed for the verification run.

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## RESULTS

Calculated radioactive emissions from the verification run are  $3 \times 10^{-10}$  microcuries for plutonium and  $3 \times 10^{-12}$  microcuries for uranium. Calculated air concentrations at the exit point from the building are  $5 \times 10^{-9}$  picocuries per cubic meter for plutonium and  $4 \times 10^{-11}$  picocuries per cubic meter for uranium. At the Plant boundary, verification run air concentrations are  $4 \times 10^{-13}$  picocuries per cubic meter for plutonium and  $4 \times 10^{-15}$  picocuries per cubic meter for uranium. For comparison, the Department of Energy Derived Concentration Guide for protection of the public is 0.02 picocuries per cubic meter for plutonium and 0.1 picocuries per cubic meter for uranium and assumes a continuous intake. The Colorado Department of Health concentration limit is 0.02 picocuries per cubic meter for plutonium and 1 picocuries per cubic meter for uranium, assuming continuous intake.

Calculated radioactive emissions for routine operations are  $1 \times 10^{-7}$  picocuries per cubic meter for plutonium and  $1 \times 10^{-11}$  picocuries per cubic meter for uranium. Air concentrations at the exit point from the building are  $6 \times 10^{-9}$  picocuries per cubic meter for plutonium and  $6 \times 10^{-13}$  picocuries per cubic meter for uranium. At the Plant boundary, routine operations air concentrations are  $5 \times 10^{-13}$  picocuries per cubic meter for plutonium and  $5 \times 10^{-17}$  picocuries per cubic meter for uranium. Again for comparison, the Department of Energy Derived Concentration Guide for protection of the public is 0.02 picocuries per cubic meter for plutonium and 0.1 picocuries per cubic meter for uranium.

Calculated radiation doses to a hypothetical individual located at the nearest Plant boundary were  $2 \times 10^{-15}$  rem from the verification run and  $7 \times 10^{-13}$  rem per year of routine operations. These values may be compared with the radiation dose standard for public protection of 0.1 rem per year for continuous exposure. Radiation dose received by Denver area residents from naturally-occurring radiation is about 0.26 rem per year. The radiation dose standard is for doses received from sources other than natural background radiation and medical sources of radiation exposures.

## DISCUSSION

In the preceding assessment, assumptions were made to simplify calculations while still providing a general indication of the magnitude of impact on public health which could be associated with the Fluidized Bed Incinerator operations. Many of the assumptions tended to overestimate the resulting emissions, concentrations, and dose values.

Plutonium is the most significant contributor to projected offsite doses, and the assumption of the amount of plutonium that

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would be involved in routine incinerator operations is greatly overestimated. Radiation doses were calculated for an individual residing continuously at the Plant boundary, impacted by the highest air concentrations in the emission plume during all periods of incineration. No individual would actually experience that much exposure.

Calculated air concentrations and resulting radiation doses are many orders of magnitude below radiation protection standards which have been adopted by the Department of Energy, the Colorado Department of Health, and the Environmental Protection Agency. The estimated radiation doses are well below the radiation doses received from natural background radiation, even using the overestimating assumptions made in this assessment. Radiation protection standards are established on the basis of comprehensive health studies and recommendations made by such scientific advisory organizations as the National Academy of Sciences, the National Council of Radiation Protection and Measurements, and the International Commission on Radiological Protection. The standards are set at levels which would result in a negligible health risk to members of the public who might be exposed to these levels. Actual radiation doses which might be received by the public as a result of the Rocky Flats Plant Fluidized Bed Incinerator operation are far below these levels.

FLUIDIZED BED INCINERATOR  
PROPOSED VERIFICATION PLAN

Run #	Type	Waste Rate Per Run (lbs/hr)	Total Waste Per Run (lbs)	CC14 Per Run (lbs)	DEPLETED URANIUM				PLUTONIUM			
					(lbs)	(g)	(Ci)	Air Concentration at Bldg. Exit (pCi/m <sup>3</sup> )	(lbs)	(g)	(Ci)	Air Concentration at Bldg. Exit (pCi/m <sup>3</sup> )
1	Liquid	36	144	7.2								
2	Liquid	60	240	12								
3	Liquid	80	320	16	0.54	247	$9 \times 10^{-5}$	$2 \times 10^{-11}$	$2 \times 10^{-15}$			
4	Solid	150	600	12	1.02	463	$2 \times 10^{-4}$	$4 \times 10^{-11}$	$4 \times 10^{-15}$			
5	Solid	105	420	8.4					$6 \times 10^{-4}$	0.27	0.02	$5 \times 10^{-9}$
6	Solid	105	420	8.4					$6 \times 10^{-4}$	0.27	0.02	$5 \times 10^{-9}$
												$4 \times 10^{-13}$
												$4 \times 10^{-13}$

## FLUIDIZED BED INCINERATOR - VERIFICATION RUN

### PLUTONIUM INCINERATION

2 runs total, 4 hours per run, 420 lbs waste per run; 100 nCi Pu per gram of waste;  
0.0732 Ci alpha activity per gram Pu, 8636 cubic meters per hour air emission flow rate;  
HEPA filter reduction factor =  $8 \times 10^{-15}$ ,  $X/Q = 3.5 \times 10^{-5}$  seconds per cubic meter

FOR EACH RUN.

#### Plutonium incinerated per run -

$$(420 \text{ lbs waste/run}) (454 \text{ g waste/lb waste}) (100 \text{ nCi Pu/g waste}) (1 \times 10^{-9} \text{ Ci/nCi}) = 0.02 \text{ Ci Pu/run}$$

#### Conversion to grams and pounds of plutonium incinerated per run -

$$(0.02 \text{ Ci Pu/run}) / (0.0732 \text{ Ci Pu/g Pu}) = 0.27 \text{ grams Pu/run}$$

$$(0.27 \text{ g Pu/run}) (0.00220 \text{ lb/g}) = 6.0 \times 10^{-4} \text{ lb Pu/run}$$

#### Total plutonium emissions -

$$(0.02 \text{ Ci/run}) (2 \text{ runs}) (1 \times 10^6 \text{ uCi/Ci}) (8 \times 10^{-15}) = 3 \times 10^{-10} \text{ uCi total plutonium emissions}$$

#### Air effluent concentration at building exit -

$$(0.02 \text{ Ci Pu/run}) (1 \times 10^{12} \text{ pCi/Ci}) (8 \times 10^{-15}) / ((8636 \text{ m}^3/\text{hr}) (4 \text{ hrs/run})) = 5 \times 10^{-9} \text{ pCi/m}^3 \text{ at building exit}$$

#### Air concentration at Plant boundary -

$$(0.02 \text{ Ci Pu/run}) (1 \times 10^{12} \text{ pCi/Ci}) (8 \times 10^{-15}) (3.5 \times 10^{-5} \text{ s/m}^3) / ((4 \text{ hr/run}) (60 \text{ min/hr}) (60 \text{ s/min})) = 4 \times 10^{-13} \text{ pCi/m}^3 \text{ at Plant boundary}$$

# FLUIDIZED BED INCINERATOR - VERIFICATION RUN

## URANIUM INCINERATION

2 runs, 4 hours per run, 320 lbs waste per liquid run, 600 lbs waste per solid run, 0.17% depleted uranium by weight,  $3.8 \times 10^{-7}$  Ci alpha activity per gram U, 8636 cubic meters per hour air emission flow rate, HEPA filter reduction factor =  $8 \times 10^{-15}$ ,  $X/Q = 3.5 \times 10^{-5}$  seconds per cubic meter

### Uranium incinerated per run -

SOLID (600 lbs waste/run)(0.0017 lb U/lb waste) = 1.02 lb U/run  
LIQUID (320 lbs waste/run)(0.0017 lb U/lb waste) = 0.54 lb U/run

### Conversion to grams and Curies of uranium incinerated per run -

SOLID (1.02 lb U/run)(454 g U/lb U) = 463 grams U/run  
LIQUID (0.54 lb U/run)(454 g U/lb U) = 247 grams U/run

SOLID (463 g U/run)( $3.8 \times 10^{-7}$  Ci U/g U) =  $2 \times 10^{-4}$  Ci U/run  
LIQUID (247 g U/run)( $3.8 \times 10^{-7}$  Ci U/g U) =  $9 \times 10^{-5}$  Ci U/run

### Total uranium emissions -

SOLID ( $2 \times 10^{-4}$  Ci U/run)(1 run)( $1 \times 10^6$  uCi/Ci)( $8 \times 10^{-15}$ ) =  $2 \times 10^{-12}$  uCi uranium emissions  
LIQUID ( $9 \times 10^{-5}$  Ci U/run)(1 run)( $1 \times 10^6$  uCi/Ci)( $8 \times 10^{-15}$ ) =  $1 \times 10^{-12}$  uCi uranium emissions  
TOTAL URANIUM EMISSIONS =  $3 \times 10^{-12}$  uCi

### Air effluent concentration at building exit -

SOLID ( $2 \times 10^{-4}$  Ci U/run)( $1 \times 10^{12}$  pCi/Ci)( $8 \times 10^{-15}$ )/((8636 m<sup>3</sup>/hr)(4 hrs/run)) =  $4 \times 10^{-11}$  pCi/r  
LIQUID ( $9 \times 10^{-5}$  Ci U/run)( $1 \times 10^{12}$  pCi/Ci)( $8 \times 10^{-15}$ )/((8636 m<sup>3</sup>/hr)(4 hrs/run)) =  $2 \times 10^{-11}$  pCi/r

### Air concentration at Plant boundary -

SOLID ( $2 \times 10^{-4}$  Ci U/run)( $1 \times 10^{12}$  pCi/Ci)( $8 \times 10^{-15}$ )( $3.5 \times 10^{-5}$  s/m<sup>3</sup>)/((4 hr/run)(60 min/hr)(60 s/min)) =  $4 \times 10^{-15}$  pCi/m<sup>3</sup> at Plant boundary  
LIQUID ( $9 \times 10^{-5}$  Ci U/run)( $1 \times 10^{12}$  pCi/Ci)( $8 \times 10^{-15}$ )( $3.5 \times 10^{-5}$  s/m<sup>3</sup>)/((4 hr/run)(60 min/hr)(60 s/min)) =  $2 \times 10^{-15}$  pCi/m<sup>3</sup> at Plant boundary

# FLUIDIZED BED INCINERATOR - VERIFICATION RUN

## RADIATION DOSE AT PLANT BOUNDARY

Breathing rate =  $2.66 \times 10^2$  milliliters per second; dose conversion factors =  $5.1 \times 10^2$  rem per microcurie, plutonium, and  $1.2 \times 10^2$  rem per microcurie, uranium

### DOSE FROM PLUTONIUM

$(4 \times 10^{-13} \text{ pCi/m}^3)(1 \times 10^{-6} \text{ uCi/pCi})(2.66 \times 10^2 \text{ ml/s})(5.1 \times 10^2 \text{ rem/uCi})(8 \text{ hr/2 runs})(60 \text{ min/hr})(60 \text{ s/min})/(1 \times 10^6 \text{ ml/m}^3) = 2 \times 10^{-15} \text{ rem/2 runs plutonium dose at Plant boundary}$

### DOSE FROM URANIUM

SOLID  $(4 \times 10^{-15} \text{ pCi/m}^3)(1 \times 10^{-6} \text{ uCi/pCi})(2.66 \times 10^2 \text{ ml/s})(1.2 \times 10^2 \text{ rem/uCi})(4 \text{ hr/1 run})(60 \text{ min/hr})(60 \text{ s/min})/(1 \times 10^6 \text{ ml/m}^3) = 2 \times 10^{-18} \text{ rem/1 run uranium dose at Plant boundary}$

LIQUID  $(2 \times 10^{-15} \text{ pCi/m}^3)(1 \times 10^{-6} \text{ uCi/pCi})(2.66 \times 10^2 \text{ ml/s})(1.2 \times 10^2 \text{ rem/uCi})(4 \text{ hr/1 run})(60 \text{ min/hr})(60 \text{ s/min})/(1 \times 10^6 \text{ ml/m}^3) = 1 \times 10^{-18} \text{ rem/1 run uranium dose at Plant boundary}$

TOTAL  $(2 \times 10^{-18} \text{ rem}) + (1 \times 10^{-18} \text{ rem}) = 3 \times 10^{-18} \text{ rem total uranium dose at Plant boundary}$

Note The uranium dose is an insignificant contributor to total dose from plutonium and uranium.

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## FLUIDIZED BED INCINERATOR - ROUTINE OPERATIONS

### PLUTONIUM INCINERATION

200 tons of waste incinerated per year; 100 nCi Pu per gram of waste, 0.0732 Ci alpha activity per gram of waste; 8636 cubic meters per hour air emission flow rate; feed rate of waste = 150 lbs per hour; HEPA filter reduction factor =  $8 \times 10^{-15}$ ,  
 $X/Q = 3.5 \times 10^{-5}$  seconds per cubic meter

#### Plutonium incinerated per year -

$(200 \text{ tons waste/year})(2000 \text{ lbs/ton})(454 \text{ g/lb})(100 \text{ nCi Pu/g waste})(1 \times 10^{-3} \text{ uCi/nCi})$   
 $= 1.8 \times 10^7 \text{ uCi maximum Pu incinerated per year}$

#### Plutonium air emissions per year -

$(1.8 \times 10^7 \text{ uCi Pu/year})(8 \times 10^{-15}) = 1 \times 10^{-7} \text{ uCi Pu/year air emissions}$

#### Air effluent concentration at building exit -

$(150 \text{ lbs waste/hr})(454 \text{ g/lb})(100 \text{ nCi Pu/g waste})(1 \times 10^3 \text{ pCi/nCi})(8 \times 10^{-15})/(8636 \text{ m}^3/\text{hr})$   
 $= 6 \times 10^{-9} \text{ pCi/m}^3 \text{ at building exit}$

#### Air concentration at Plant boundary -

$(150 \text{ lbs waste/hr})(454 \text{ g/lb})(100 \text{ nCi Pu/g waste})(1 \times 10^3 \text{ pCi/nCi})(8 \times 10^{-15})(3.5 \times 10^{-5} \text{ s/m}^3)$   
 $/((60 \text{ min/hr})(60 \text{ s/min})) = 5 \times 10^{-13} \text{ pCi/m}^3 \text{ at Plant boundary}$

## FLUIDIZED BED INCINERATOR - ROUTINE OPERATIONS

### URANIUM INCINERATION

200 tons of waste incinerated per year; 100 nCi Pu per gram of waste; 8636 cubic meters per hour air emission flow rate, feed rate of waste = 150 lbs per hour; concentration of uranium =  $1 \times 10^4$  picocuries per liter; HEPA filter reduction factor =  $8 \times 10^{-15}$ ;  $X/Q = 3.5 \times 10^{-5}$  seconds per cubic meter

#### Uranium incinerated per year -

$(200 \text{ tons waste/year})(2000 \text{ lbs/ton})(1 \times 10^4 \text{ pCi U/l waste})(1 \times 10^{-6} \text{ uCi/pCi})/((0.264 \text{ gal/l})(8.5 \text{ lbs/gal})) = 1.78 \times 10^3 \text{ uCi uranium incinerated per year}$

#### Uranium air emissions per year -

$(1.78 \times 10^3 \text{ uCi U/year})(8 \times 10^{-15}) = 1 \times 10^{-11} \text{ uCi/year air emissions}$

#### Air effluent concentration at building exit -

$(150 \text{ lbs waste/hr})(1 \times 10^4 \text{ pCi U/l waste})(8 \times 10^{-15})/((8.5 \text{ lb/gal})(0.264 \text{ gal/l})(8636 \text{ m}^3/\text{hr})) = 6 \times 10^{-13} \text{ pCi/m}^3 \text{ at building exit}$

#### Air concentration at Plant boundary -

$(150 \text{ lbs waste/hr})(1 \times 10^4 \text{ pCi U/l waste})(8 \times 10^{-15})(3.5 \times 10^{-5} \text{ s/m}^3)/((8.5 \text{ lb/gal})(0.264 \text{ gal/l})(60 \text{ min/hr})(60 \text{ s/min})) = 5 \times 10^{-17} \text{ pCi/m}^3 \text{ at Plant boundary}$

FLUIDIZED BED INCINERATOR - ROUTINE OPERATIONS

RADIATION DOSE AT PLANT BOUNDARY

Breathing rate =  $2.66 \times 10^2$  milliliters per second; dose conversion factors =  $5.1 \times 10^2$  rem per microcurie, plutonium, and  $1.2 \times 10^2$  rem per microcurie, uranium

Hours of incineration operation per year -

$(200 \text{ tons waste/year})(2000 \text{ lb/ton})/(150 \text{ lb/hr}) = 2667 \text{ hours/year incinerator operating}$

Dose from plutonium -

$(5.3 \times 10^{-13} \text{ pCi/m}^3)(2667 \text{ hr/year})(60 \text{ min/hr})(60 \text{ s/min})(2.66 \times 10^2 \text{ ml/s})(1 \times 10^{-6} \text{ uCi/pCi})$   
 $(5.1 \times 10^2 \text{ rem/uCi})/(1 \times 10^6 \text{ ml/m}^3) = 7 \times 10^{-13} \text{ rem/year plutonium dose at Plant boundary}$

Dose from uranium -

$(5.2 \times 10^{-17} \text{ pCi/m}^3)(2667 \text{ hr/year})(60 \text{ min/hr})(60 \text{ s/min})(2.66 \times 10^2 \text{ ml/s})(1 \times 10^{-6} \text{ uCi/pCi})$   
 $(1.2 \times 10^2 \text{ rem/uCi})/(1 \times 10^6 \text{ ml/m}^3) = 2 \times 10^{-17} \text{ rem/year uranium dose at Plant boundary}$

Note The uranium dose is an insignificant contributor to total dose.

## FLUIDIZED BED INCINERATOR

## REFERENCES

- US80 U.S. Department of Energy, April 1980, Environmental Impact Statement, Rocky Flats Plant Site, DOE/EIS-0064, Washington, D.C.
- In79 International Commission of Radiological Protection, 1979, Annals of the ICRP: ICRP Publication 30, Limits for Intakes of Radionuclides by Workers, Pergamon Press Ltd., Oxford, England.